adsorbed fraction, which was eluted with Skellysolve B, gave 0.36 g. (20%) of a colorless oil. The oil was treated with 0.39 g. of *s*-trinitrobenzene in alcohol, giving yellow crystals, m.p. 76.2–78.2° (not recrystallized). *Anal.* Calcd. for $C_{16}H_{14}\cdot C_6H_3N_3O_6$: C, 63.0; H, 4.1. Calcd. for $C_{16}H_{16}\cdot C_6H_3N_3O_6$: C, 62.7; H, 4.5. Found: C, 62.4; H, 4.2. A sample of the complex (0.55 g.) was chromatographed on alumina, giving 0.25 g. of a yellow oil (II or isomer) which was dehydrogenated by treatment with 0.06 g. of palladium-on-charcoal.[6] The fluoranthene formed was isolated as the *s*-trinitrobenzene complex, m.p. 208.5–209.4°, mixed m.p. 208.6–209.4°; the identification was confirmed by the ultraviolet absorption spectrum. The yield of III from II was 33%.

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[6] R. P. Linstead and S. L. S. Thomas, *J. Chem. Soc.*, 1172 (1940); catalyst-*d*.

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The Preparation of 3,4-Dimethoxy-2,5-dicarbethoxythiophene. 3,4-Dimethoxythiophene

BY C. G. OVERBERGER AND JOGINDER LAL[1]

In connection with other work we had occasion to prepare certain thiophene derivatives for comparison with the corresponding thiophene dioxides. Fager[2] has described the preparation of 3,4-dimethoxythiophene by the reaction of the sodium salt obtained from the condensation of ethyl thiodiacetate and ethyl oxalate with methyl sulfate, subsequent hydrolysis with base to give the 3,4-dimethoxy-2,5-dicarboxythiophene followed by decarboxylation. However, no physical constants except a boiling point and no analysis were reported. Turnbull[3] has reported the preparation of 3,4-dimethoxythiophene by the reaction of diazomethane with 3,4-dihydroxythiophene prepared by the decarboxylation of 3,4-dihydroxy-2,5-dicarboxythiophene and reported a boiling point and correct analytical data. He likewise describes the preparation of 3,4-dimethoxythiophene from 3,4-dimethoxy-2,5-dicarboxythiophene by decarboxylation but he does not compare the product obtained with that from the previous procedure. He does not state how the 3,4-dimethoxy-2,5-dicarboxythiophene was prepared.

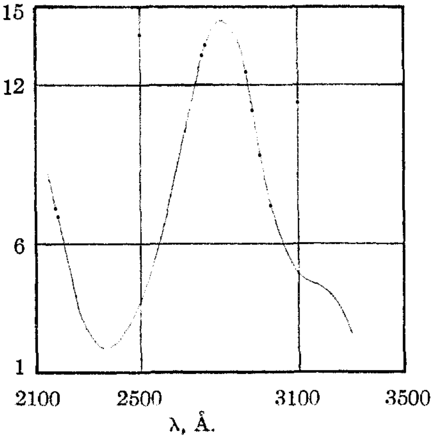

Fig. 1.—Ultraviolet absorption spectrum of 3,4-dimethoxy-2,5-dicarbethoxythiophene in 95% ethanol.

Since the Fager procedure for preparing 3,4-dimethoxythiophene was experimentally more desirable from the viewpoint of quantity, it was necessary for us to establish the authenticity of heretofore non-isolated intermediates and the product. Reaction of the sodium salt obtained from the condensation of ethyl oxalate and ethyl thiodiacetate with methyl sulfate and isolation of the diester directly gave a 51% yield of 3,4-dimethoxy-2,5-dicarbethoxythiophene. This compound was identical with the product obtained by reaction of 3,4-dihydroxy-2,5-dicarbethoxythiophene with diazomethane (95%). This was demonstrated by a mixed melting point and their identical ultraviolet absorption spectra (Fig. 1). This comparison now enabled us to use the general Fager procedure with assurance. Saponification of 3,4-dimethoxy-2,5-dicarbethoxythiophene gave a 92% yield of 3,4-dimethoxy-2,5-dicarboxythiophene. A methoxyl determination demonstrated that two O-methyl groups were present. Decarboxylation of this diacid was effected by heating with copper at 180–190° in vacuum to give an 87.5% yield of pure 3,4-dimethoxythiophene. The 3,4-dimethoxythiophene was further characterized by formation of the 2,5-dinitro derivative.

New derivatives of 3,4-dihydroxy-2,5-dicarbethoxythiophene, the diacetate and dibenzoate are described in the experimental section.

3,4-Dihydroxy-2,5-dicarbethoxythiophene.—This compound was prepared according to the procedure of Hinsberg.[4] From 35 g. (1.52 moles) of sodium in 350 ml. of alcohol, 146 g. (1 mole) of ethyl oxalate and 103 g. (0.5 mole) of ethyl thiodiacetate, there was obtained 102 g., m.p. 134 (78.5%). The sodium salt is isolated in our procedure. Recrystallization from benzene or methanol gave a m.p. 134.5–135° (134°, no yield reported).[4]

(A) **Dibenzoate.**—The reaction of 3,4-dihydroxy-2,5-dicarbethoxythiophene with benzoyl chloride and pyridine[5] gave the dibenzoate. The product was recrystallized twice from hexane to give transparent regular crystals, m.p. 96.5–97.5°.

Anal. Calcd. for $C_{24}H_{20}O_8S$: C, 61.53; H, 4.30. Found: C, 61.34; H, 4.22.

(B) **Diacetate.**—The reaction of 3,4-dihydroxy-2,5-dicarbethoxythiophene with acetic anhydride and sodium acetate gave the diacetate.[6] The product was crystallized from 95% ethanol to give transparent crystals, m.p. 80.5–81.2°.

Anal. Calcd. for $C_{14}H_{16}O_8S$: C, 48.83; H, 4.68. Found: C, 48.64; H, 4.94.

3,4-Dimethoxy-2,5-dicarbethoxythiophene (A).—Methylation of 3,4-dihydroxy-2,5-dicarbethoxythiophene was carried out with diazomethane.[7] To a cold solution of 9 g. (0.0346 mole) of 3,4-dihydroxy-2,5-dicarbethoxythiophene dissolved in 50 ml. of pure dioxane was added with gentle shaking a cold ethereal solution of about 8.5 g. of diazomethane. The reaction mixture was surrounded by ice and allowed to stand for 1–2 hours and then washed with dilute hydrochloric acid to destroy excess diazomethane. The diazomethane-free solution was washed several times with five per cent. sodium carbonate solution to neutralize traces of hydrochloric acid and to remove any unconverted 3,4-dihydroxy-2,5-dicarbethoxythiophene. The ethereal layer

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[1] A portion of a thesis by Joginder Lal submitted to the Polytechnic Institute of Brooklyn in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

[2] E. W. Fager, THIS JOURNAL, 67, 2217 (1945).

[3] S. G. Turnbull, U. S. Patent 2,453,103, November 2, 1948.

[4] Hinsberg, *Ber.*, 43, 901 (1910).

[5] R. L. Shriner and R. C. Fuson, "Identification of Organic Compounds," 3rd edition, John Wiley and Sons, Inc., New York, N. Y., 1948, p. 164.

[6] *Ibid.*, p. 165.

[7] F. Arndt, "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., second edition, p. 165.

was concentrated and a few ml. of water added to the concentrate. On cooling, white needles of 3,4-dimethoxy-2,5-dicarbethoxythiophene were obtained. A further yield of crystals was obtained from the mother liquor by additional concentration. Crystallization from an alcohol–water mixture gave white needles, m.p. 52–53°, 9.5 g. (95.4%).

Anal. Calcd. for $C_{12}H_{16}O_6S$: C, 49.99; H, 5.59. Found: C, 50.13; H, 5.47.

(B) 3,4-Dimethoxy-2,5-dicarbethoxythiophene was also prepared by methylation of the sodium salt, obtained by the reaction between ethyl thiodiacetate and ethyl oxalate, with methyl sulfate. Finely powdered sodium salt (30 g.) was placed in a 500-ml. flask and 80 g. of freshly distilled methyl sulfate was added quickly. The flask was fitted with a reflux condenser having a calcium chloride drying-tube and the contents of the flask were refluxed gently for one-half hour. Excess of methyl sulfate was removed by distillation under reduced pressure. The residue in the flask was treated with 5 per cent. sodium carbonate solution and stirred thoroughly for about 15 minutes to decompose excess methyl sulfate. The contents were cooled in an ice-bath and the solid removed by filtration. The residue was washed with ice-water and the sticky mass was dissolved in a methanol–water mixture and crystallized using Norite. The product could be further purified by recrystallization from petroleum ether or a methanol–water mixture as a solvent to give white needles, m.p. 52–53°, 14.6 g. (50.7%) based on the weight of ethyl thiodiacetate used, mixed m.p. 52–53°.

The ultraviolet absorption spectra in 95% alcohol (Fig. 1) of the dimethoxy compounds were identical.

3,4-Dimethoxy-2,5-dicarboxythiophene.—To a solution of 3 g. (0.0104 mole) of 3,4-dimethoxy-2,5-dicarbethoxythiophene in 100 ml. of methanol in a 250-ml. flask fitted with a reflux condenser was added 2 g. (0.036 mole) of potassium hydroxide in 100 ml. of water and the contents were refluxed for 2 to 4 hours. On cooling, the crystalline mass separated out and was removed by filtration. It was dissolved in a small amount of water, cooled and acidified with dilute hydrochloric acid solution. A further amount of the compound was obtained by concentrating the methanol mother liquor and acidifying with dilute hydrochloric acid as described above. The combined product was crystallized twice from methanol to give white material decomposing at 260° without melting, 2.21 g. (91.5%). Fager[2] reported a decomposition at 250° and a yield of 58.8% based on the weight of methyl thiodiacetate. Fager[2] did not isolate a dimethoxy methyl ester but saponified the reaction mixture from the condensation to obtain the diacid directly.

Anal. Calcd. for $C_8H_8O_6S$: neut. equiv., 116.1; $-OCH_3$, 26.73. Found: neut. equiv., 116; $-OCH_3$, 26.65.

The Fager[2] procedure was repeated to give an identical acid; dec. point, 258°. Ethyl thiodiacetate was used instead of the methyl ester employed by Fager.

3,4-Dimethoxythiophene.—An intimate mixture of 15 g. (0.0647 mole) of 3,4-dimethoxy-2,5-dicarboxythiophene and 2 g. of copper powder was placed in a 150-ml. flask. The latter was connected to a condenser, a receiver and two Dry Ice traps. The flask was heated to 180–190° under a vacuum of about 20–40 mm. The distillate from the receiver and the traps was taken up in ether and the ethereal layer concentrated. The concentrate was then distilled through a small center tube column. The 3,4-dimethoxythiophene distilled at 110° (17 mm.), $n^{25}\text{D}$ 1.5386, d^{25}_4 1.2081, 8.15 g. (87.5%). Turnbull[3] reported a b.p. of 100–101.5° (10–11 mm.) and a yield of 70% by reaction of 3,4-dihydroxythiophene with diazomethane. Fager[2] reported a b.p. 108–115° (12 mm.) and a yield of 58% by decarboxylation of 3,4-dimethoxy-2,5-decarboxythiophene with copper chromite in quinoline, but no analysis is given.

Anal. Calcd. for $C_6H_8O_2S$: C, 50.00; H, 5.55. Found: C, 50.34; H, 5.69.

The 3,4-dimethoxythiophene was also prepared according to the procedure described by Fager except that copper powder was used instead of copper chromite. However, the product obtained by this procedure could not be purified and characterized.

3,4-Dimethoxy-2,5-dinitrothiophene.—The nitration of 3,4-dimethoxythiophene was carried out in a similar manner to that described for 2-nitrothiophene in reference 8. From 4 g. (0.0274 mole) of dimethoxythiophene dissolved in 25 ml. of acetic anhydride and 8 g. (0.12 mole) of fuming nitric acid in 50 ml. of glacial acetic acid, crude yellow crystals were obtained. The crystals were washed with ice-water, pressed and dried in a vacuum desiccator. The dry mass was crystallized from petroleum ether (b.p. 60–68°), using Norite to give 4 g. of yellow, needle-like crystals, m.p. 110–115°. Recrystallization twice from petroleum ether (b.p. 60–68°), gave bright yellow needles, m.p. 116.5–117.2°, 3 g. (46.2%).

Anal. Calcd. for $C_6H_6O_6SN_2$: C, 30.80; H, 2.54. Found: C, 30.79; H, 2.58.

Ultraviolet Absorption Spectrum.—The ultraviolet absorption spectrum of 3,4-dimethoxy-2,5-dicarbethoxythiophene was determined with a Beckman quartz ultraviolet spectrophotometer with 95% ethanol as the solvent. The spectrum is shown in Fig. 1 in which the molar extinction coefficients are plotted against the wave lengths in ångström units.

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[8] V. S. Babasinian, "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., second edition, p. 466.

The Characterization of Indole-3-acetic Acid and its Esters[1]

BY CARL T. REDEMANN, SYLVAN H. WITTWER AND HAROLD M. SELL

Although several of the esters of indole-3-acetic acid have been described previously[2,3,4] the only means of characterizing these compounds besides saponification and identification of the resulting hydrolysis products has been conversion to the picrates. Hydrolysis followed by identification of the liberated alcohol is a very difficult process when only minute quantities of material, such as might be isolated from plant tissues, are available. Unfortunately, the picrates of many of the esters are so readily soluble that identification of an ester by conversion to the picrate is also unsatisfactory for use with milligram quantities of the esters.

The reaction of 1,3,5-trinitrobenzene with indole-3-acetic acid, as well as with the indole-3-acetates which we have prepared, leads to the formation of addition products which crystallize well, have distinct melting points, and are sufficiently insoluble in cold ethanol to permit ready purification of small quantities of derivative by recrystallization from this solvent.

Experimental

Preparation of the Esters.—The esters of indole-3-acetic acid were prepared from the free acid and the appropriate alcohol, with hydrogen chloride catalyst, as described by Jackson for the ethyl ester.[3] The yields ranged from 60 to 90%.

Inasmuch as neither the *n*-butyl nor the *n*-amyl esters of indole-3-acetic acid have thus far been described, they were recrystallized from petroleum ether (b.p. 30–60°) and analyzed. Their properties are summarized in Table I.

TABLE I

PROPERTIES OF ESTERS OF INDOLE-3-ACETIC ACID

Ester	M.p., °C.	B.p., °C.	B.p., Mm.	Analysis, % Calcd. C	Calcd. H	Calcd. N	Found C	Found H	Found N
n-Butyl	29–30	155	0.1	72.7	7.4	6.1	72.7	7.2	6.3
n-Amyl	34–35	156	0.02	73.4	7.8	5.7	73.6	7.7	5.8

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[2] T. Hoshino and K. Shimodaira, *Ann.*, **520**, 19 (1935).

[3] R. W. Jackson, *J. Biol. Chem.*, **88**, 659 (1930).

[4] F. Kögl and D. G. F. R. Kostermans, *Z. physiol. Chem.*, **235**, 201 (1935).